May 2002 • NREL/CP-520-32215

Conference Paper

Solar Decathlon: Collegiate Challenge to Build the Future

Preprint

C. Warner, R. Nahan, and M. Eastment
National Renewable Energy Laboratory

R. King
U.S. Department of Energy

To be presented at the 29th IEEE PV Specialists Conference
New Orleans, Louisiana
May 20-24, 2002

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393

NREL is a U.S. Department of Energy Laboratory
Operated by Midwest Research Institute • Battelle • Bechtel

Contract No. DE-AC36-99-GO10337

SOLAR DECATHLON: COLLEGIATE CHALLENGE TO BUILD THE FUTURE

Cecile Warner,* Richard King,** Ruby Nahan,* Mark Eastment*
*NREL, 1617 Cole Blvd., Golden, CO 80401 USA
**U.S. Department of Energy, 1000 Independence Ave., S.W., Washington, DC 20585

ABSTRACT

A new collegiate competition, called the Solar Decathlon, is under way. Fourteen teams from colleges and universities across the United States, including Puerto Rico, will assemble on the National Mall in Washington, DC, in late September 2002. They will compete to capture, convert, store, and use enough solar energy to power small, solar-powered, energy-efficient homes that they have designed, built, and transported to the site. Solar Decathletes will be required to provide all the energy for an entire household, including a home-based business and the transportation needs of the household and business. During the event, only the solar energy available within the perimeter of each house may be used to generate the power needed to compete in the ten Solar Decathlon contests. The event is sponsored by the U.S. Department of Energy, National Renewable Energy Laboratory, and private-sector partners BP Solar, American Institute of Architects, Electronic Data Systems, and Home Depot.

BACKGROUND

According to *Solar Electric Power, the U.S. Photovoltaic Industry Roadmap* [1], the industry goal is to "meet 10% of U.S. peak generation capacity by 2030." This aggressive goal will be met by a mixture of applications, at least half of which will be distributed generation (0.5 kW–10 MW), largely comprising grid-connected systems in the built environment. By 2020, the bulk of these systems are projected be in the residential and commercial building sectors. Beginning in 2005, a significant and fast-growing component of the growth will be building-integrated photovoltaics (BIPV) systems—those with the PV integrated directly into the building skin or façade. To achieve the projected market penetration for BIPV, we must tackle key market barriers to widespread adoption. These market barriers include simplifying the architectural integration of PV into buildings, toward achievement of common building practices; demonstrating aesthetic and functional applications; and expanding the availability of design choices in BIPV products to appeal to a wider audience of project designers and builders.

One of the most compelling opportunities for BIPV systems lies in their potential to enable a building to produce as much energy as it consumes—or more. Although there are a handful of examples of such net zero-energy buildings worldwide, this application of PV remains the exception, not the rule. In addition to the market barriers described above, BIPV applied to zero-energy buildings also faces daunting technical barriers.

Possibly the most significant technical barrier to the widespread adoption of BIPV-equipped, zero-energy buildings is the need to coordinate among many participants early in the building design and throughout the construction process. These participants, such as architects, engineers, and building tradespeople, traditionally do not communicate extensively (or at all) during the design and construction of a typical new building. All of the energy systems of the building—including the building envelope itself, space-conditioning system, hot water system, lighting, and energy-efficient appliances—must be addressed holistically throughout the design and construction to ensure that the electric loads are minimized, and that the BIPV system can meet the anticipated remaining electrical loads. Other (non-PV) solar energy systems, even though they may compete for rooftop space with the BIPV system, must be considered and incorporated as appropriate to meet the building's nonelectric energy loads.

To bring attention to the topic of energy demands in the built environment and to the integrated, interdisciplinary approach required to meet building energy requirements with solar energy, a new approach is needed. The mechanism of a collegiate competition can provide the motivation to take a fresh look at this complex problem. A competition, held in the national spotlight, provides a compelling incentive to engage in creative thinking. Furthermore, a college campus is a natural interdisciplinary resource. Architects and engineers, the primary participants in the evolution of net zero-energy buildings, will work in collaboration for the first time as students, setting the stage for a career of collaboration. A lasting outcome of such a competition is the inspiration of the best and brightest students to engage the problems inherent in developing and applying solar energy products. The next generation of practitioners will therefore be equipped with a background in solar energy technologies that will last throughout their careers. The U.S. Department of the Energy and the National Renewable Energy Laboratory (NREL) have successfully used the competition format in their series of Sunrayce [2] (now the American Solar Challenge) competitions, from 1993–1999.

Based in part on the success of these past collegiate competitions, the Solar Decathlon—a competition to design, build, and operate the most effective solar-powered house—was conceived and developed. Envisioned as a biennial event, the first Solar Decathlon was launched in October, 2000, and will culminate in a week of side-by-

side competition on the National Mall in Washington, DC, in autumn 2002.

THE SOLAR DECATHLON

Sponsors

The Solar Decathlon is sponsored by the U.S. Department of Energy (DOE), NREL, and private-sector partners BP Solar, the American Institute of Architects (AIA), Electronic Data Systems (EDS), and the Home Depot. Each sponsor brings a component of the critically needed expertise to carry out the event, and each has a business interest in the outcome of the event.

Most of the cost to build and transport their entries is being borne by the student teams. DOE provided $5,000 to each team to assist the students with their fundraising efforts, and will be providing identical electric cars (the Think Neighbor, by Ford Motor Company) to each team for use in the event. Both BP Solar and the Home Depot are providing attractive pricing on their products to Solar Decathlon teams, and both will provide experts during the event. EDS is providing Internet connectivity and the associated supporting hardware, software, and expertise for the event. The AIA will build on its past accomplishments in working to promote PV and other new building energy technologies to its practicing-architect members [3] by supporting the selection of distinguished jurors and by promoting the event to schools of architecture and the broader architectural community.

Chronology

During 2000 and 2001, NREL and DOE worked together to develop a format for the event and a set of rules and regulations that would encourage the development of small, solar-powered homes that are simultaneously well-designed, aesthetically pleasing, energy-efficient, technologically advanced, and yet user-friendly. In October 2000, a solicitation to colleges and universities across the United States was released, particularly targeting schools of architecture and schools of engineering, and encouraging collaboration among these departments. Eleven teams were announced as participants by Energy Secretary Spenser Abraham in April 2001. Three more teams were selected to join in August 2001.

Although most of the Solar Decathlon projects have been under way for more than a year at the individual collegiate competitors, the event will become most visible to the general public when it culminates in head-to-head contests in energy and design from September 26–October 5, 2002.

Ground rules

In addition to being entirely dependent on solar energy, the homes are also subject to the competition ground rules. The venue selected for the first Solar Decathlon—the National Mall in Washington, DC—is perhaps the most visible piece of real estate in the United States. The site of many memorable public gatherings and demonstrations, the property located between the Capitol and the Washington Monument known as the National Mall land is managed by the National Park Service and governed by its rather stringent regulations. The permit for the use of the National Mall is limited to a maximum of 21 days, including set-up, take-down, and holding the actual event. To be open to the public, each home and all event structures must provide a handicapped-accessible route for tours that complies with the Americans with Disabilities Act.

The portion of the National Mall that the Solar Decathlon will occupy is bounded by 4th Street, 7th Street, Madison Street, and Jefferson Street. Each team is provided with an equally sized lot of about 5500 sq. ft. Teams are allowed to build within an 800-sq.-ft footprint, and each home must contain a minimum of 450 sq. ft. of conditioned space. Homes are limited to a maximum 18-ft height limit, and must be built within an imaginary “solar envelope” defined in the contest regulations that limit shading of neighbors. All structures must comply with applicable electrical, mechanical, and structural codes. Round-trip transport to the competition site, and assembly and disassembly of the entry, is the responsibility of the teams. Each team may have a maximum of six Decathletes participating in the competition at a time during competition hours. During the event, teams are required to operate (using only solar energy) the home and all associated appliances, the car, and a home-based communications business. Penalties will be assessed for non-compliance.

The 10 Solar Decathlon contests

The Solar Decathlon consists of 10 contests that encompass all of the ways in which we use energy in our daily lives—at work, at home, and at play. Each contest is worth 100 points, except for the Design and Livability contest, which is worth 200 points. The motivation for awarding additional points to design reflects the importance of the architectural component of this competition.

The event will illustrate how solar energy can improve our quality of life. Solar energy is clean; it significantly reduces pollutant emissions. And solar energy is renewable, thereby increasing our nation's energy security. The Solar Decathlon will also teach the student participants and the general public about how energy is used in their daily lives, and it will illustrate how energy intensive different daily activities are.

The competition will demonstrate that market-ready technologies, including photovoltaics, exist that can meet the energy requirements of our daily activities by tapping into the sun's power.

Finally, because design is a critical element in the scoring of this contest, the Solar Decathlon will show that solar energy can meet our household needs while providing an aesthetically pleasing structure in which to live, work, and play.

Design and Livability

A jury of distinguished architects will judge design, innovation, and aesthetics. The challenge of this contest will be to successfully integrate and synthesize design and solar energy and energy efficiency technologies into a livable and delightful domestic environment.

Design Presentation and Simulation

Before a project is built, the designers imagine the project through drawings, models, and computer models. This contest evaluates the production of an imaginative and thorough set of documents illustrating the construction of each team's house and the simulation of its energy performance.

Graphics and Communication

Each team will be required to produce its own Web site, newsletters, and other outreach materials, as well as provide live tours of their houses to the visiting public. The goal of this contest is to effectively explain the solar energy and energy efficiency technologies used in the competition house.

The Comfort Zone

Space heating and cooling are the largest users of energy in residential buildings. Electrical space cooling is expected to increase the use of energy in the next 20 years. This contest will demonstrate that each Solar Decathlon house is designed to maintain interior comfort through natural ventilation, heating, cooling, and humidity controls while using a minimum amount of energy supplied entirely by the sun.

Refrigeration

Every modern home and office has a refrigerator and freezer, a fact that represents an opportunity for energy savings. The challenge of this contest is to maintain appropriate temperatures in a refrigerator and freezer while minimizing energy use. Points will be awarded based on how consistently the refrigerator and freezer maintain interior temperatures throughout the competition week.

Hot Water

Heating water with the sun is one of the easiest and least expensive solar energy technologies a homeowner can install to save money and reduce fossil fuel consumption. This contest demonstrates that a solar house can provide all of the energy necessary to heat water for common uses such as bathing, laundry, and dishwashing.

Energy Balance

The object of this contest is to begin and end the competition with the same amount of energy stored in the battery system, demonstrating that the sun can supply the energy necessary for all the daily energy demands of a small household and home-based business.

Lighting

Electrical lighting is the third largest consumer of energy in buildings. Sunlight, moonlight, and artificial light all contribute to the livability of a house, inside and out. This contest judges the energy efficiency of the lighting in the house as well as the elegance and quality during both the day and night.

Home Business

Appliances such as personal computers, televisions, fax machines, and other electronic equipment are the biggest consumers of energy in buildings (commercial and residential combined). Almost all offices and most homes (especially as telecommuting gains popularity) now have these kinds of devices. This contest will require that the houses can provide enough power to satisfy the energy needs of a small business operated from the home.

Getting Around

Every year, the personal transportation needs of Americans—getting to and from work, school, and play—is growing. The transportation contest of the Solar Decathlon evaluates how much "extra" energy a competition house can generate to transport Solar Decathletes around town in a street-legal, commercially-available electric vehicle.

THE 2002 SOLAR DECATHLON TEAMS

Fourteen student teams will compete to capture, convert, store, and use enough solar energy to power our modern lifestyle for 8 days in 2002. Solar Decathletes will be required to provide all the energy for an entire household, including a home-based business and the transportation needs of the household and business. During the event, only the solar energy available within the perimeter of each house may be used to generate the power needed to compete in the 10 Solar Decathlon contests. Table 1 lists the 14 Solar Decathlon teams. Teams have already selected “lots” on the Solar Decathlon site on the National Mall. The village layout appears in Figs. 1 and 2.

Table 1. 2002 Solar Decathlon Teams.

Auburn University
Carnegie Mellon University
Crowder College
Texas A&M University
Tuskegee University
University of Colorado at Boulder
University of Delaware
University of Maryland
University of Missouri—Rolla & Rolla Technical Institute
University of North Carolina—Charlotte
University of Puerto Rico
University of Texas at Austin
University of Virginia
Virginia Polytechnic Institute and State University

CONCLUSION

The Solar Decathlon will be a living demonstration laboratory for consumers. Communication is a key part of

the competition. Each team will have a Web site, provide house tours, and create print materials that explain the design, engineering, and operation of their house as well as the products and technologies being used in the house. For more information, please visit the Web site at http://www.solardecathlon.org/.

Research and development endeavors in energy efficiency and solar energy technologies have improved our lives. The Solar Decathlon will not only have an immediate effect on consumers by educating them about solar energy and energy-efficient products, but it will affect the future as well. The competition will provide stimulus to the next generation of researchers, architects, engineers, and builders as they prepare to begin their careers.

REFERENCES

[1] Energetics, Inc., ed., *Solar Electric Power--The U.S. Photovoltaic Industry Roadmap*. NREL Report No. BR-520-30150. (May 2001) 36 pp.

[2] E. Nelsen and C. Leboeuf (1994). "Sunrayce 93: Solar Car Racing Offers Students and the General Public an Exciting Introduction to Solar Energy Technologies." *Solar Today*. Vol. 8(1), Jan/Feb 1994; pp. 21-22.

[3] S. Vierra and C. Warner. (1996). "AIA Solar Electric Building Programs for Architects." R. Campbell-Howe and B. Wilkins-Crowder, eds. *Solar 96: Proceedings of the 1996 American Solar Energy Society Annual Conference, 13-18 April 1996, Asheville, North Carolina*. Boulder, CO: American Solar Energy Society; pp. 68-71; NICH Report No. 23298.

Fig. 1. Site plan of the Solar Decathlon village on the National Mall.

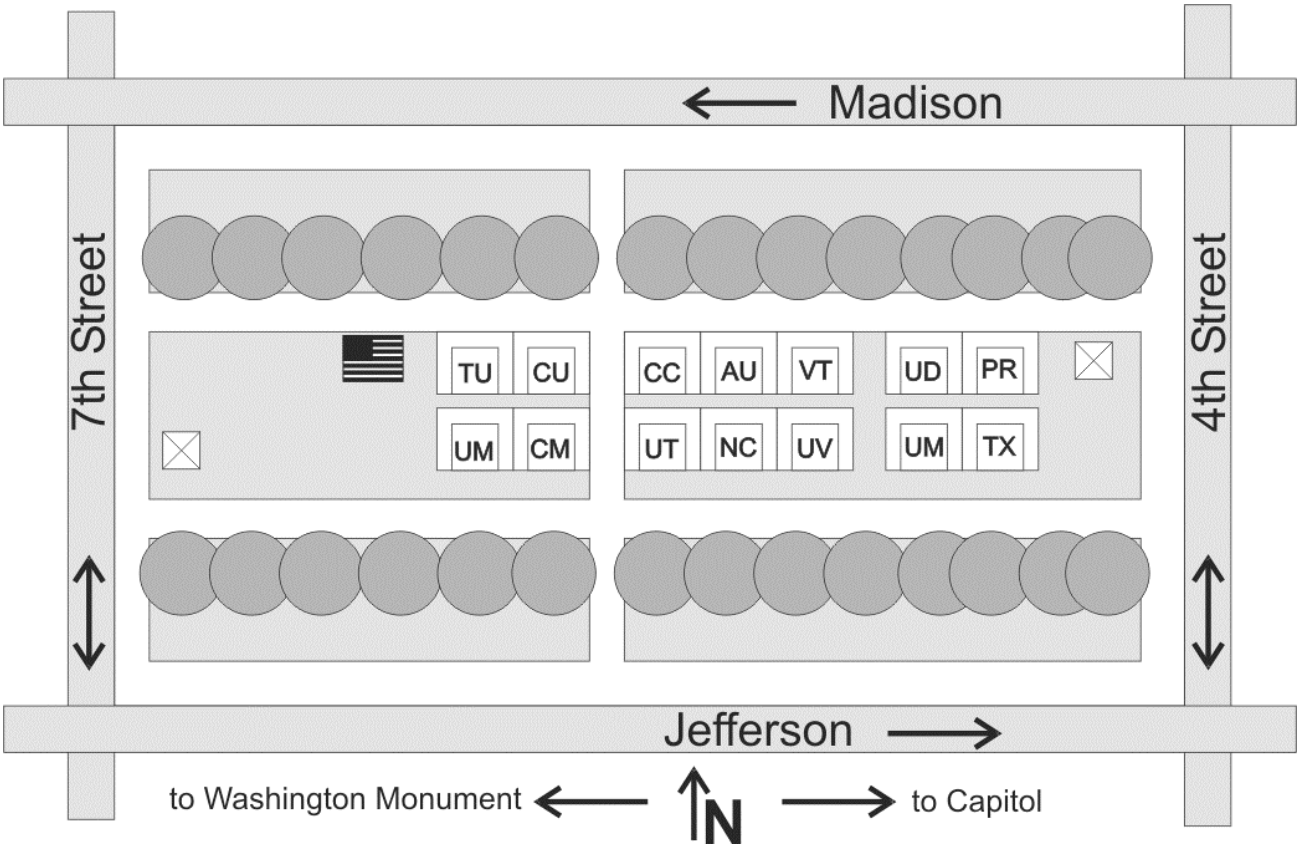

Fig. 2. Solar Decathlon layout on the National Mall.

REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 2002	29th IEEE PVSC-Conference Paper May 20-24 2002

4. TITLE AND SUBTITLE
Solar Decathlon: Collegiate Challenge to Build the Future; Preprint

5. FUNDING NUMBERS
PVP28103

6. Author(S)
C. Warner,* R. King,** R. Nahan,* M. Eastment*

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
*National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401-3393
** U.S. Department of Energy, 1000 Independence Ave., S.W., Washington, DC 20585

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NREL/CP-520-32215

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words*: A new collegiate competition, called the Solar Decathlon, is under way. Fourteen teams from colleges and universities across the United States, including Puerto Rico, will assemble on the National Mall in Washington, DC, in late September 2002. They will compete to capture, convert, store, and use enough solar energy to power small, solar-powered, energy-efficient homes that they have designed, built, and transported to the site. Solar Decathletes will be required to provide all the energy for an entire household, including a home-based business and the transportation needs of the household and business. During the event, only the solar energy available within the perimeter of each house may be used to generate the power needed to compete in the ten Solar Decathlon contests. The event is sponsored by the U.S. Department of Energy, National Renewable Energy Laboratory, and private-sector partners BP Solar, American Institute of Architects, Electronic Data Systems, and Home Depot.

14. SUBJECT TERMS: PV; Solar Decathlon; energy-efficient homes; collegiate competition; building-integrated photovoltaics (BIPV); solar energy technology;

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102